Towards a low-power exclusion

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Where we are today

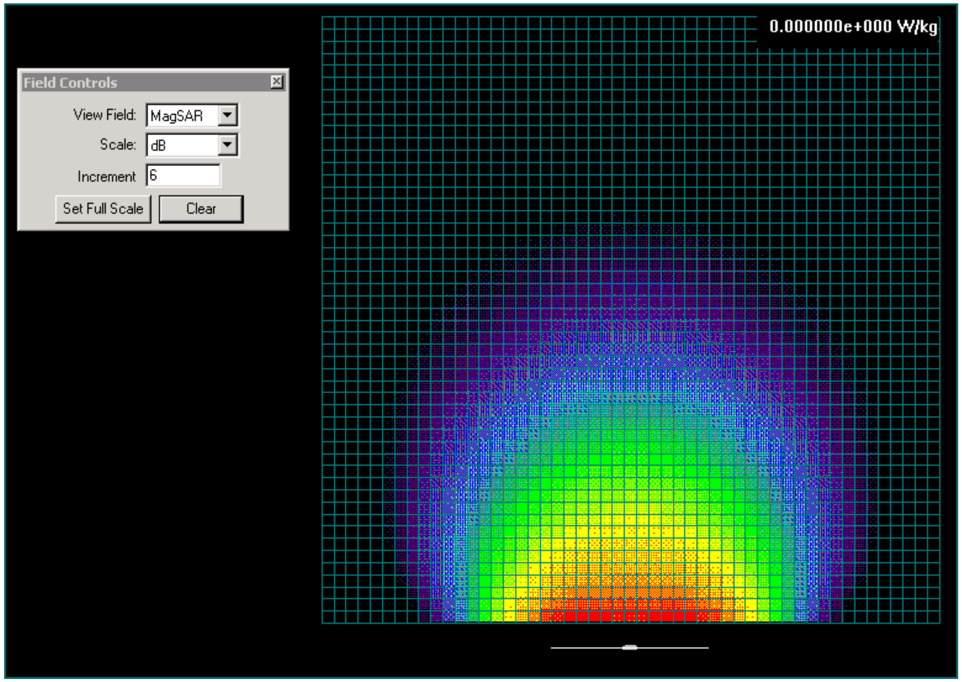
- IEEE limit (1.6 mW/g, 1-g)
  - Products emitting less than 1.6 mW can be safely excluded from SAR testing
- ICNIRP limit (2 mW/g, 10-g)
  - Products emitting less than 20 mW can be safely excluded from SAR testing

Goal of the study

- Define conservative conditions to determine maximum localized SAR (1-g & 10-g) that can be produced in body exposed in the near field of an RF sources in the 300-3000 MHz band
- Determine the corresponding maximum RF power levels that can produce exposure levels that are still compliant with applicable exposure limits under those conditions

“Experimental” conditions

- Flat phantom
  - P1528 “head simulating tissue” properties
- Short dipole
  - $\sim\lambda_0/10$ long
  - Parallel orientation



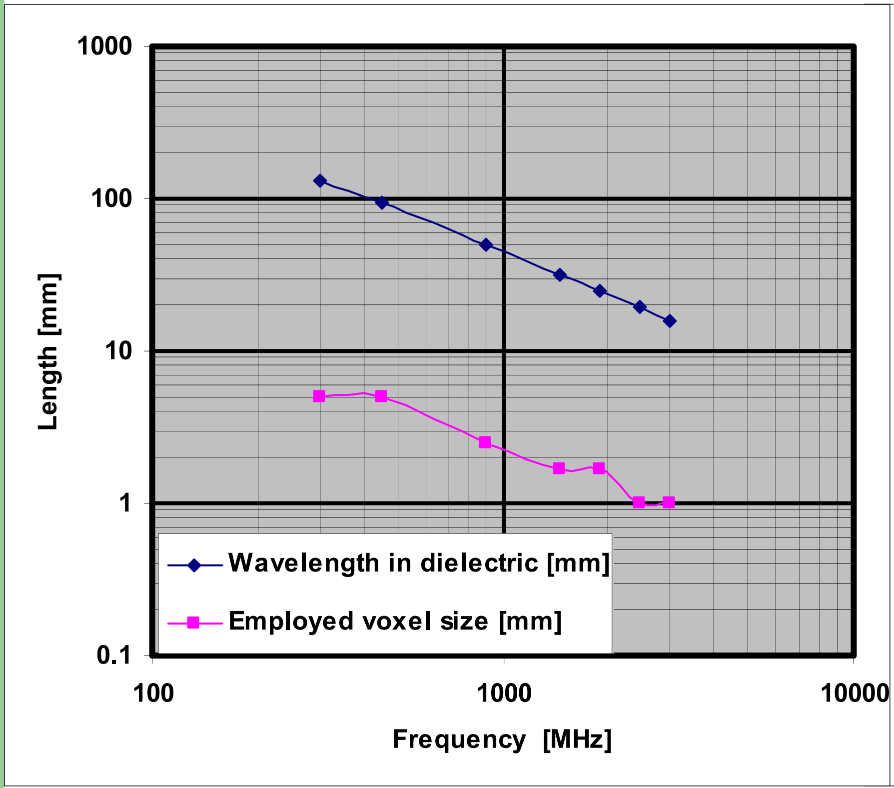
Computational tool

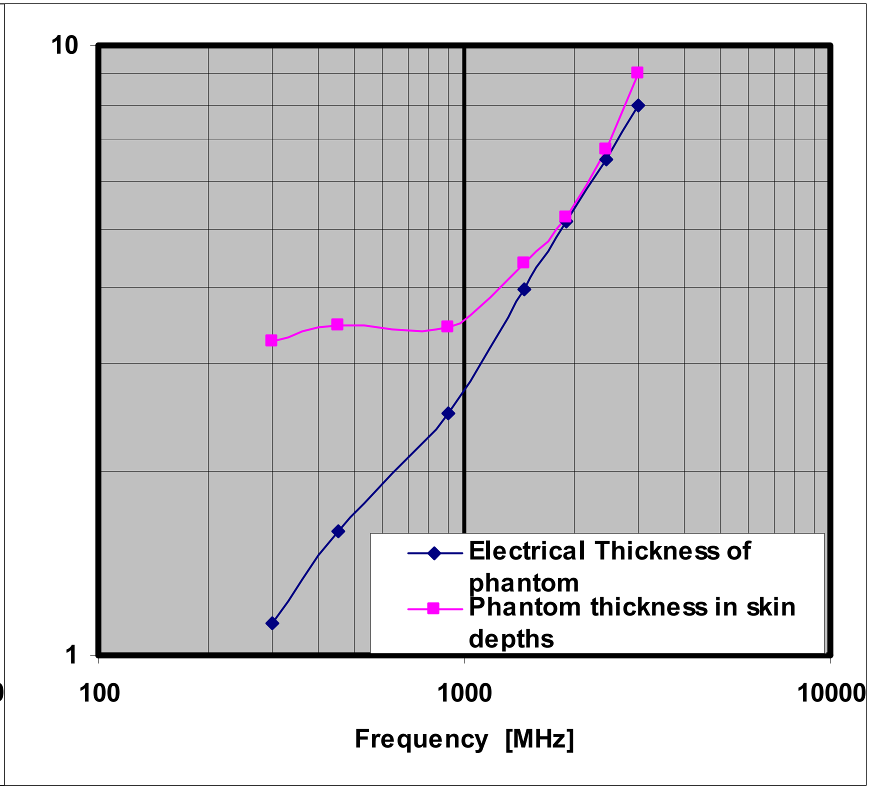
- XFDTD™ v5.3 by Remcom
  - Uniform voxel size in all three dimensions
    - 5 mm minimum step
  - Liao's surface ABC
    - at least ten voxel clearance
  - Center-fed wire antenna
    - odd number of voxels
  - Thevenin source with sinusoidal excitation
    - at least ten periods
  - Simultaneous 10-g and 1-g SAR estimation

Simulation details

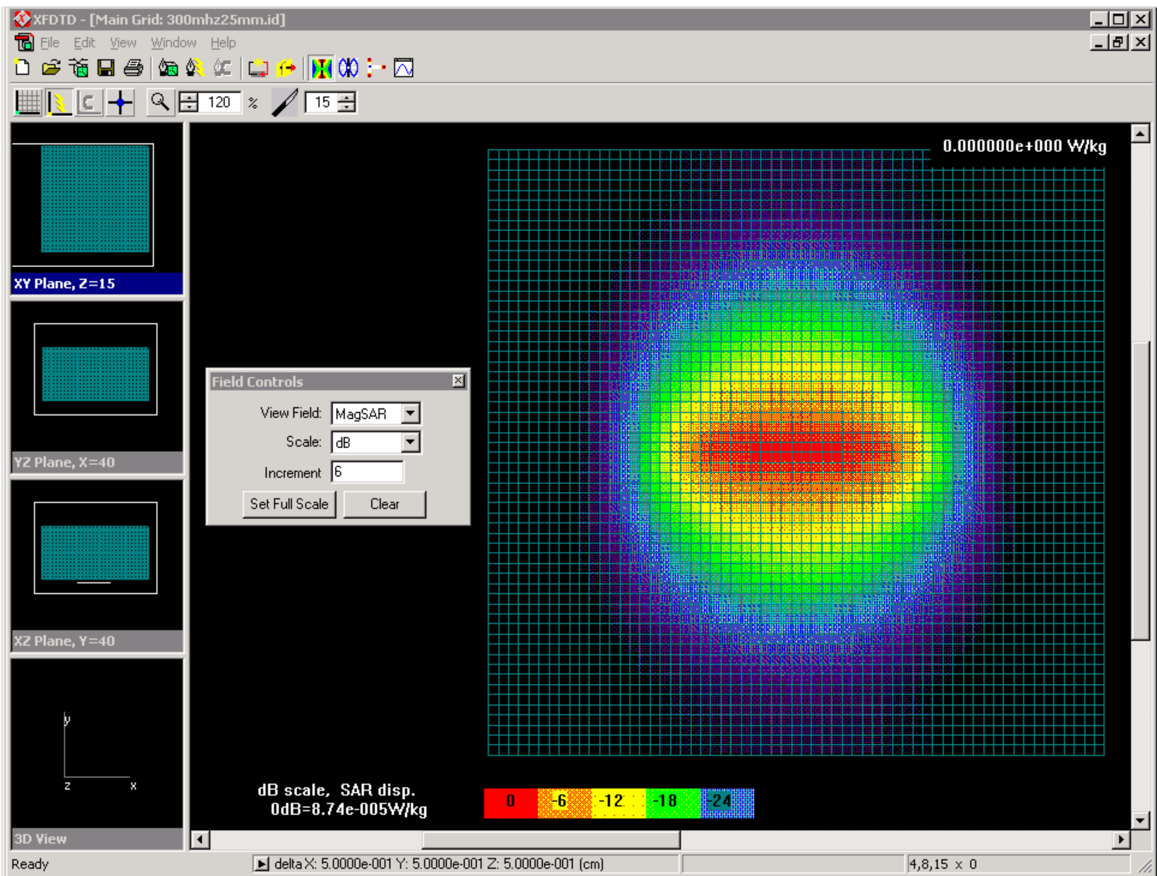
Frequency [MHz]	300	450	900	1450	1900	2450	3000
Relative Permittivity	45	44	42	41	40	39	39
Conductivity [S/m]	0.87	0.87	0.97	1.2	1.4	1.8	2.4
Wavelength [cm]	100	66.7	33.3	20.7	15.8	12.2	10
Wavelength in dielectric [mm]	133	94	50	32	25	19	16
Maximum allowable voxel size [mm]	13.3	9.4	5.0	3.2	2.5	1.9	1.6
Employed voxel size [mm]	5	5	2.5	1.67	1.67	1	1
Dipole length in Voxels	19	13	13	11	9	11	9
Dipole electrical length	0.095	0.098	0.098	0.089	0.095	0.090	0.090
Flat phantom edge size in Voxels	60	40	50	76	76	126	126
Flat phantom edge size [cm]	30	20	12.5	12.67	12.67	12.6	12.6
Flat phantom height in Voxels	30	30	50	76	76	126	126
Flat phantom height [cm]	15	15	12.5	12.67	12.67	12.6	12.6
One cm distance in Voxels	2	2	4	6	6	10	10
2.5 cm distance in Voxels	5	5	10	15	15	25	25

Model consistency (i)





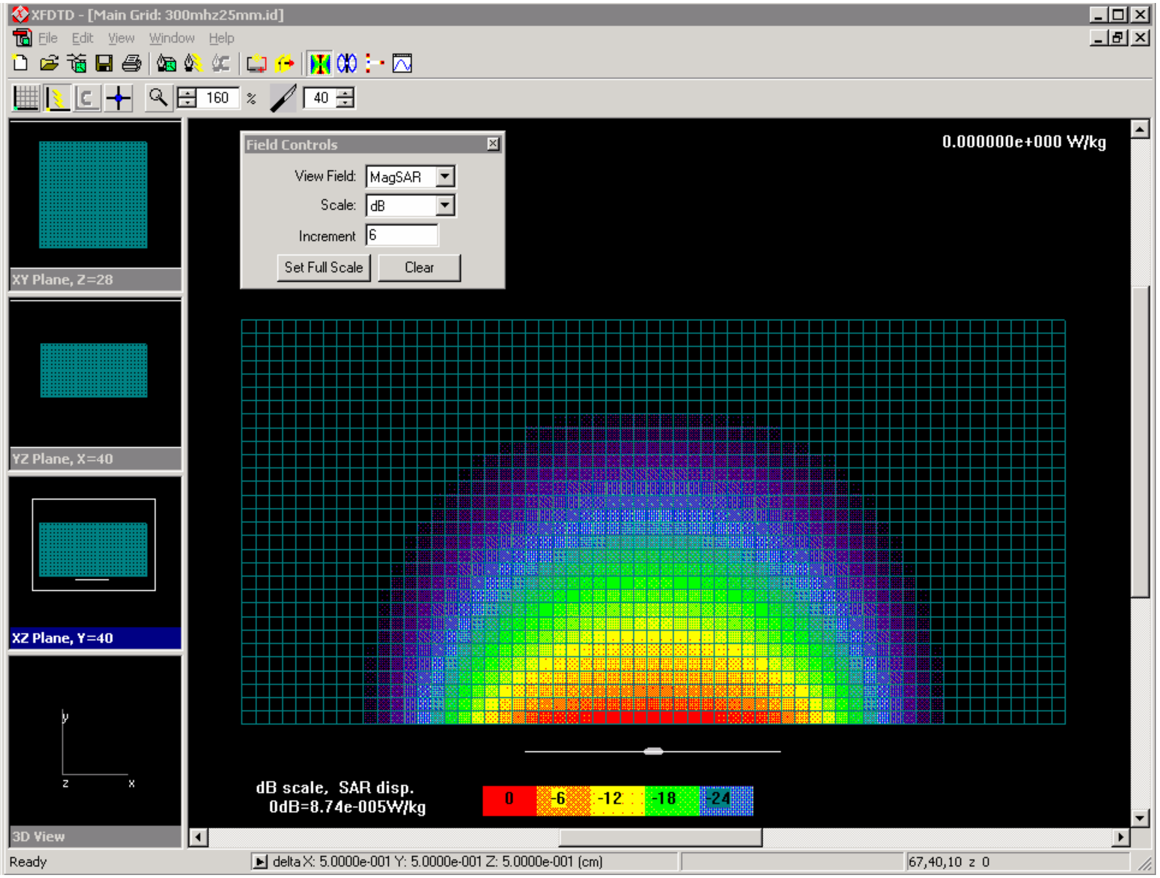
Model consistency (ii)



300 MHz

Electrically smallest phantom

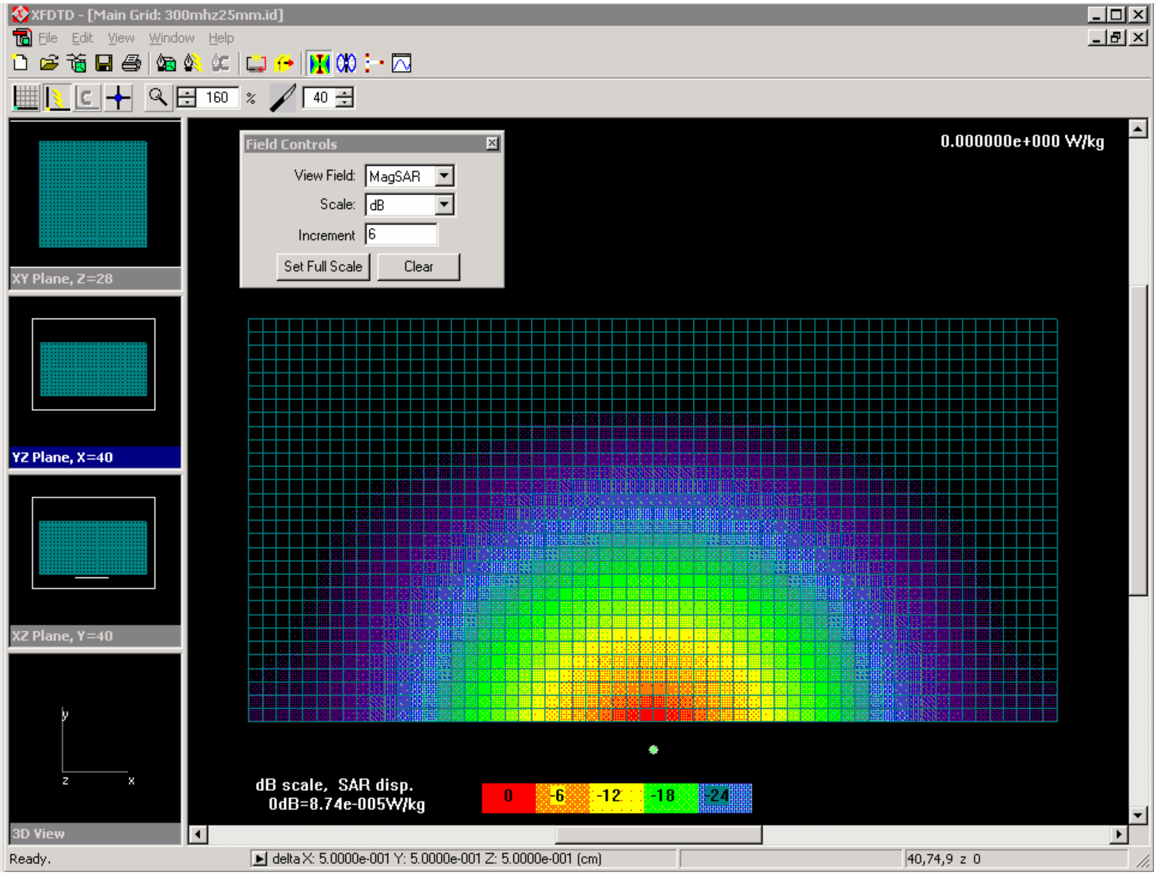
Model consistency (iii)



300 MHz

Electrically smallest phantom

Model consistency (iv)

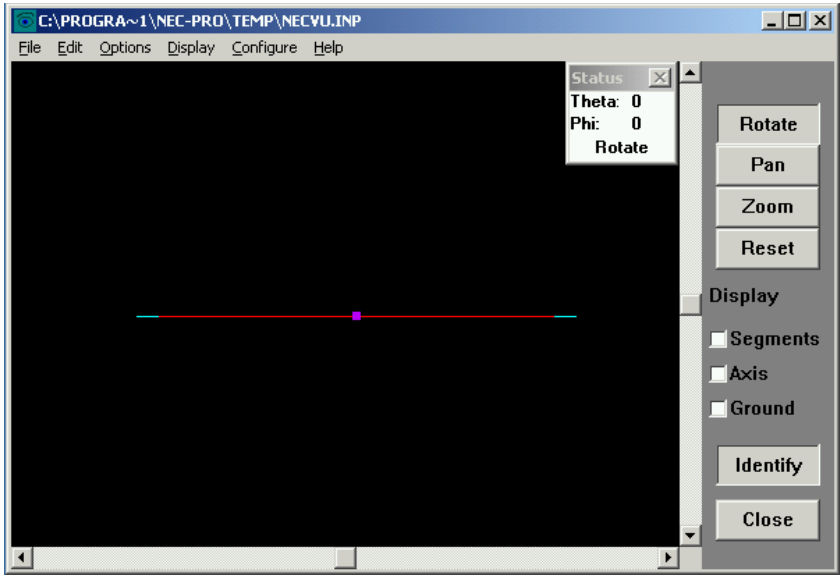


300 MHz

Electrically smallest phantom

Antenna characteristics

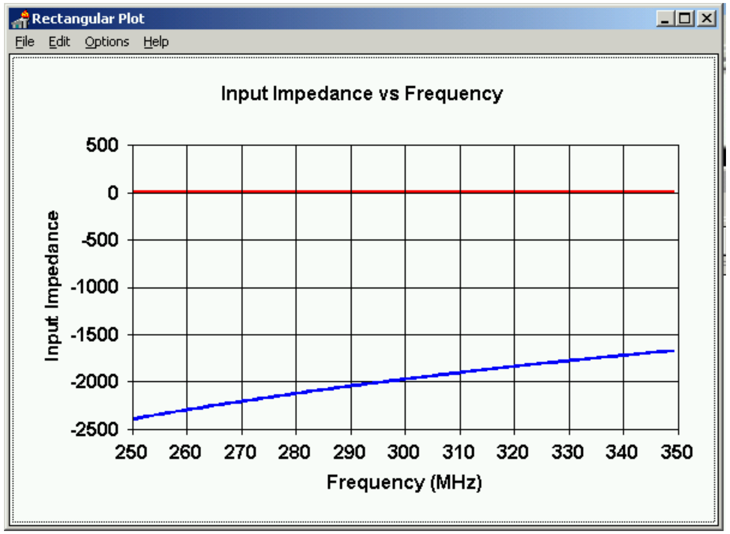
- Center-fed, short (λ_0/10) dipole
  - High EM energy density for a set output power
  - Low radiation resistance requires high feed-point current to emit a given amount of RF power
  - High H-field produces high localized SAR

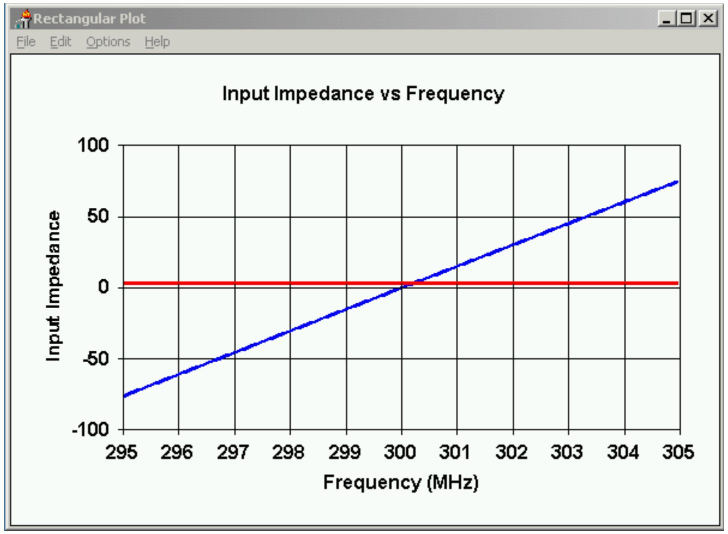


- Will also investigate small loop antenna

Bandwidth @ 300 MHz (free-space)

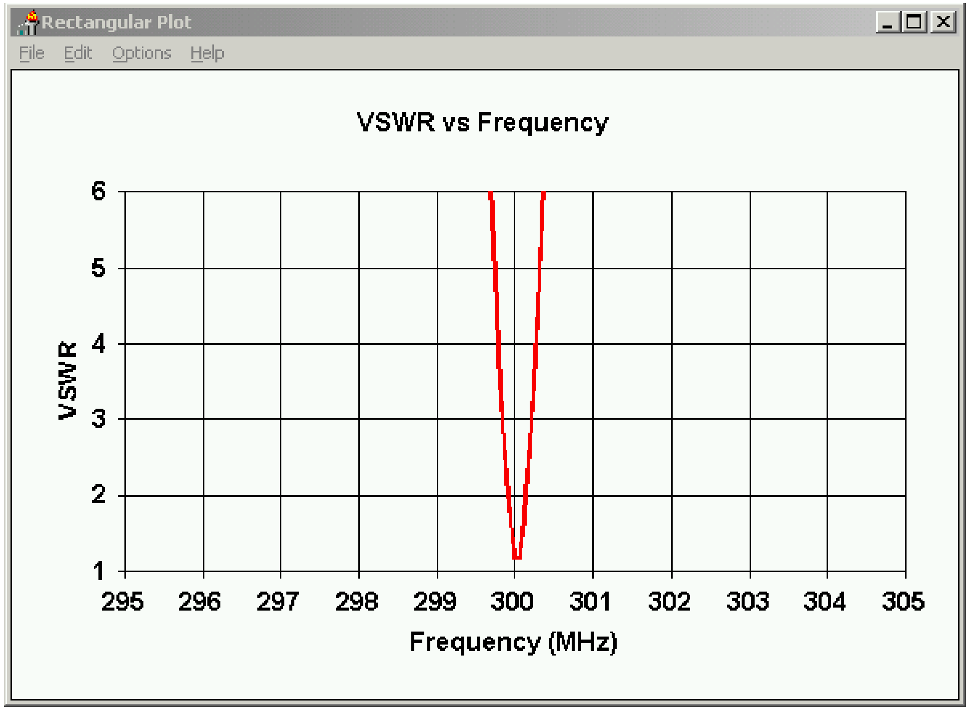
- Capacitive impedance compensated with series inductance





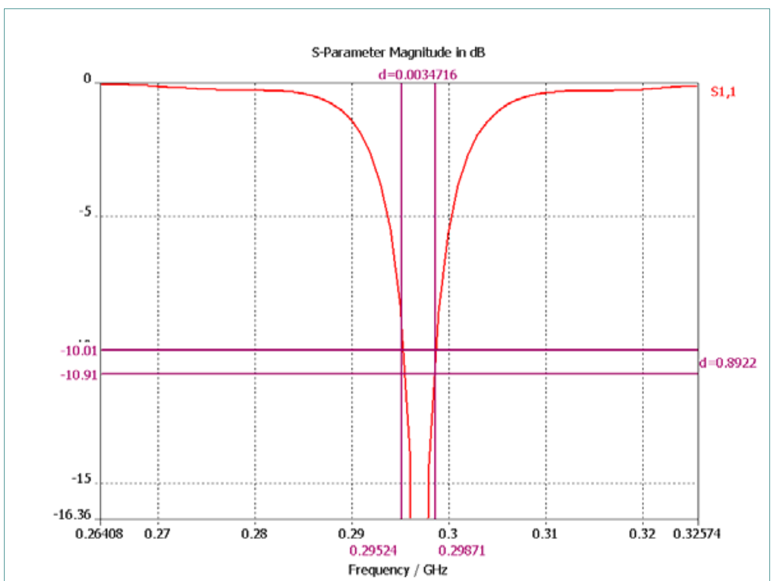
Best achievable FS bandwidth

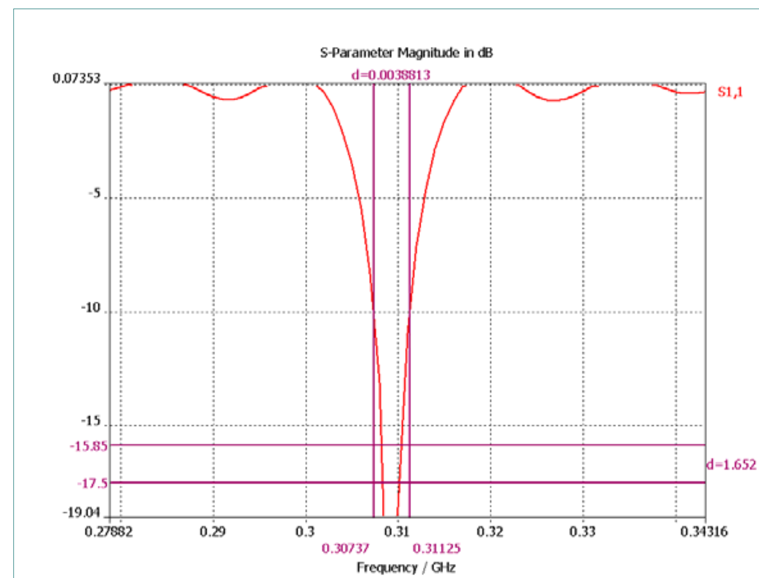
- VSWR relative to 2.5 Ω source resistance
  - 200 kHz 2:1 BW (<<1%)
  - 400 kHz 3:1 BW (~0.15%)
  - 700 kHz 6:1 BW (~0.25%)



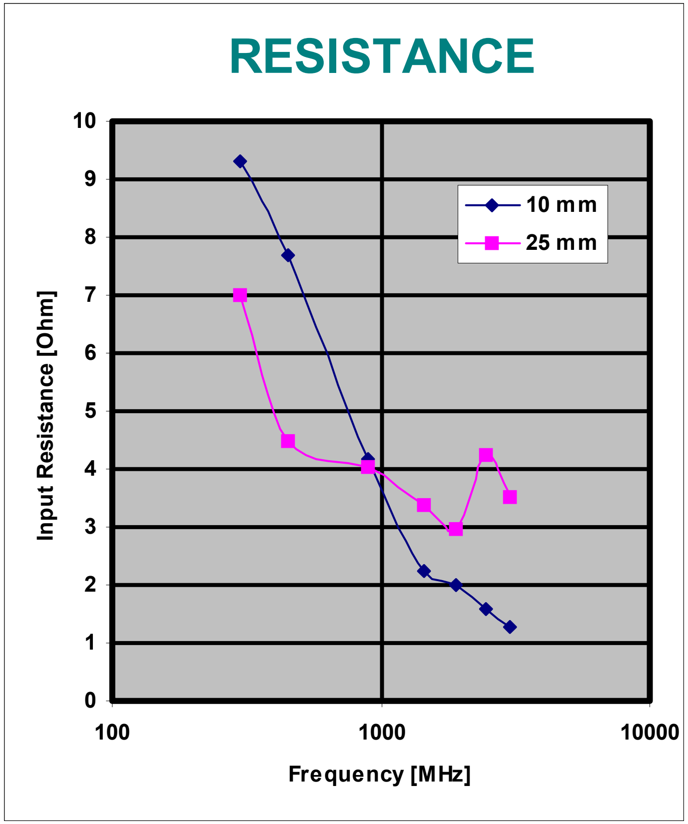
Bandwidth @ 300 MHz (loaded)

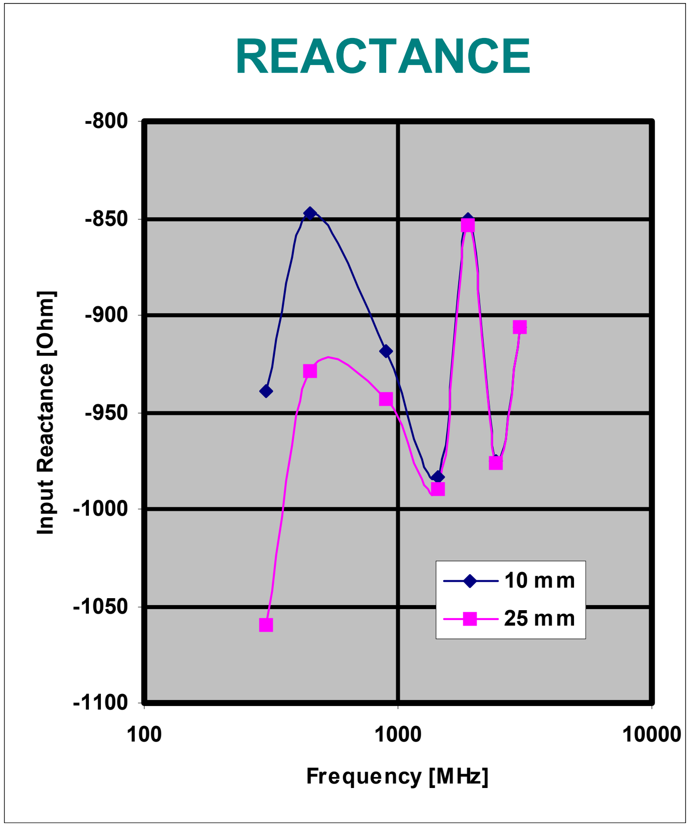
- Best achievable 2:1 SWR bandwidth ~1%
  - Significantly detuned (~3%) going from 1 cm to 2 cm distance from the lossy body



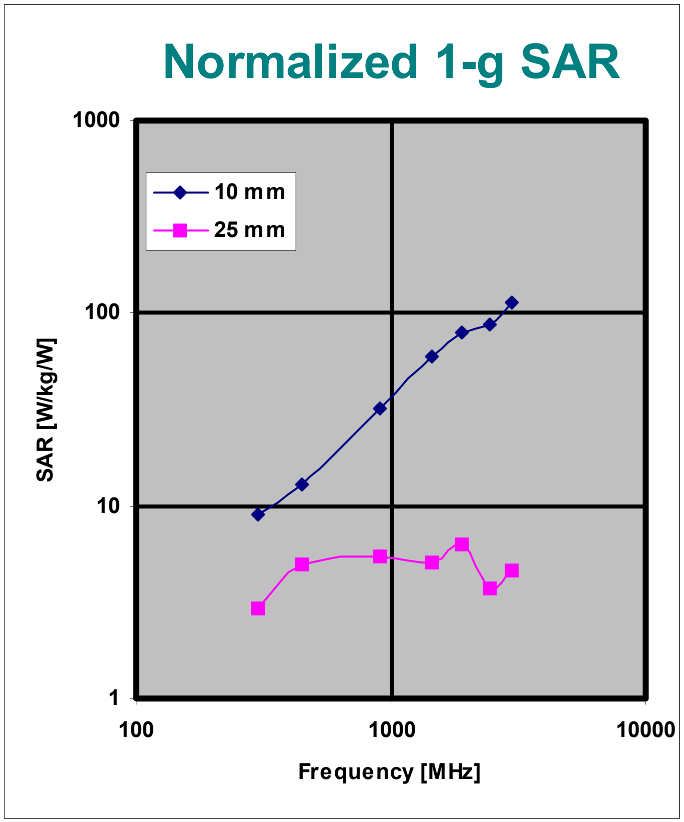


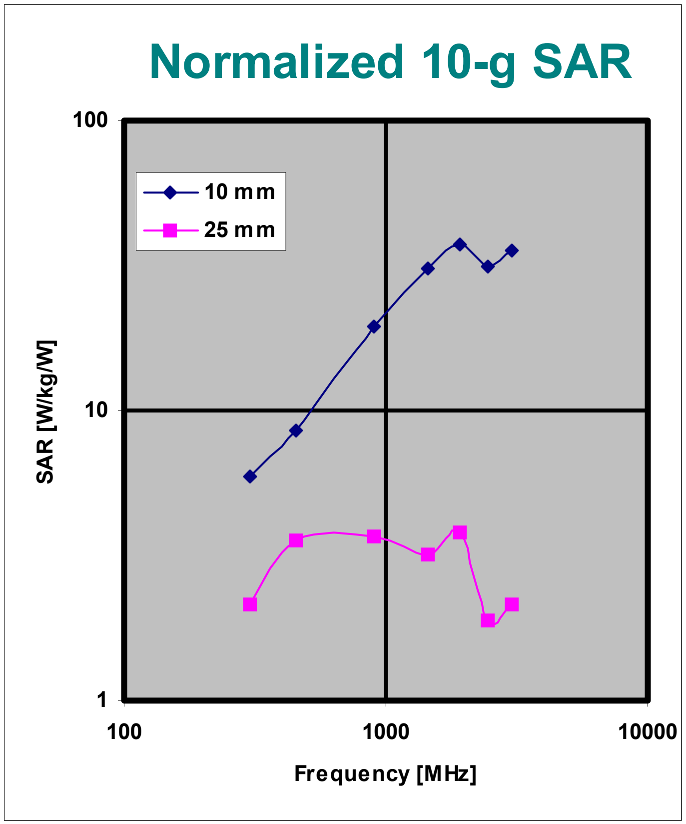
Input impedance



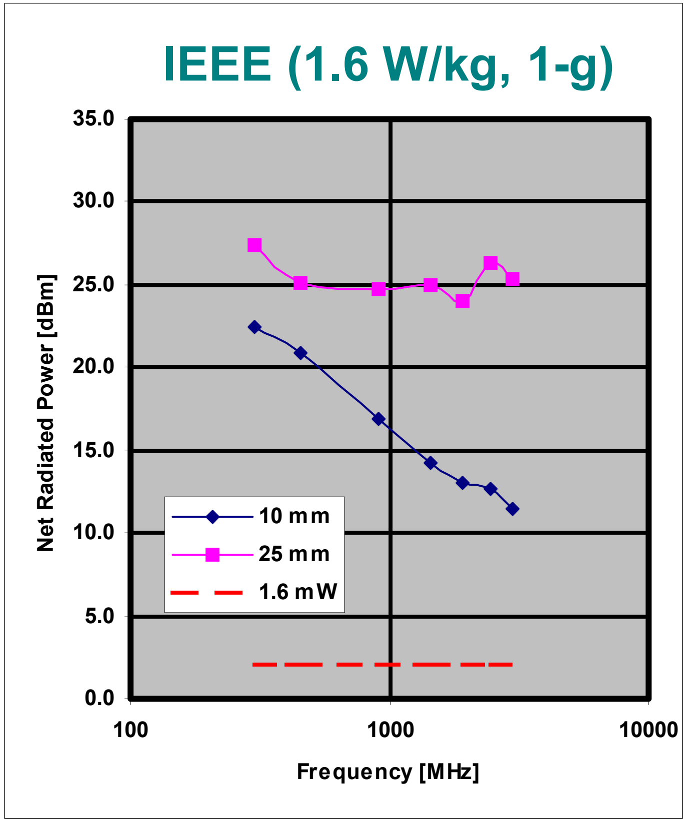


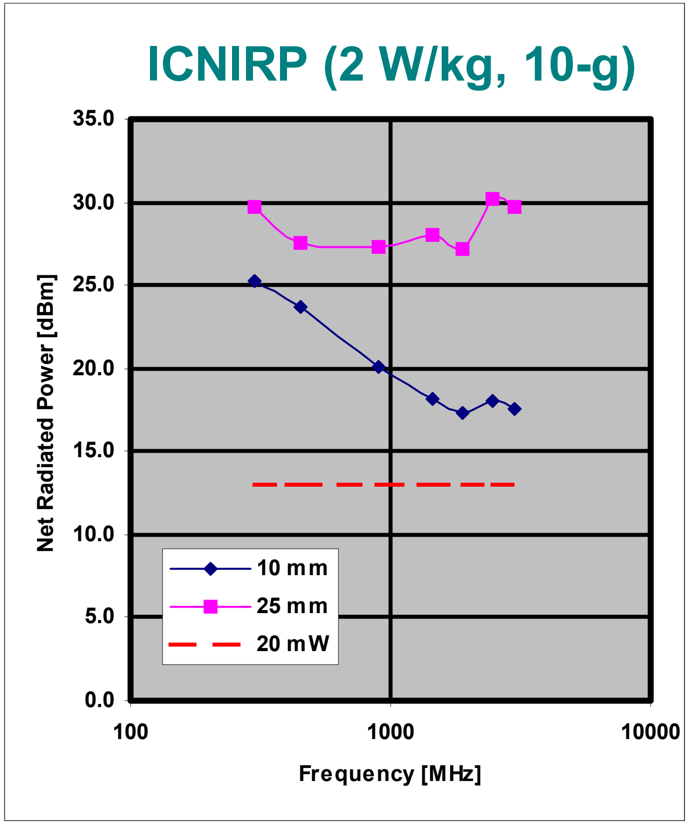
SAR per Watt


Normalized 1-g SAR
1000
100
10
1
100
1000
10000
10 mm
25 mm
SAR [W/kg/W]
Frequency [MHz]


Normalized 10-g SAR
100
10
1
100
1000
10000
10 mm
25 mm
SAR [W/kg/W]
Frequency [MHz]

Max allowed power





Notes

- Markedly different SAR behavior between 10 mm and 25 mm source distance
  - Sharp SAR increase for 10 mm,
  - Modest SAR fluctuation for 25 mm
  - Possible explanation: Higher electrical distance produce higher wave impedance at the dielectric interface, thus producing higher reflected power
    - Kuster-Balzano formula predicts such general behavior

Notes

- Source model seems too conservative
  - High-Q (narrow bandwidth) and uncertain proximity to the body produce unreliable impedance match
    - No one would use a 1% bandwidth small antenna to be operated in undefined position near high-ε_r objects
  - Low source resistance, capacitive reactance require use of matching techniques that reduce efficiency
    - Maybe, the exclusion table should be based on a two-dimensional “frequency/fractional bandwidth” table

Inputs received so far

- Use frequency AND bandwidth criteria
  - Chu’s limit provides a bandwidth upper-bound for a given electrical volume of the antenna
  - Wider band is achieved using longer dipole antenna
- Compare SAR “imprints” with worst-case distributions defined in P1528
  - Relate our model with realistic product behaviors
  - We might find out we’ve been way too conservative

Proposal

- Form a small task force
  - Replicate FDTD simulations
  - Refine simulation model(s)
  - Perform select validation measurements
  - Compare findings with available product data, e.g., from FCC type approval database
  - Produce final report to SCC34-SC2